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The bizarre Eustigmatacean alga, *Pseudostaurastrum limneticum* (Borge) Chodat, in a shallow, nutrient-enriched Scottish loch: new to the British Isles

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The yellow-green alga *Pseudostaurastrum* is a unicellular genus belonging to the phylum of Eustigmatophyta, formerly transferred from the Xanthophyta by Schnepf *et al.* (1996). Recently, the phylogenetic position of *Pseudostaurastrum* was investigated using 18S rRNA gene sequences and it was confirmed that *P. limneticum* and *P. enorme* form a sister branch to other Eustigmatophyceans included in the study (Hegewald *et al.*, 2007; Přibyl *et al.*, 2012).

Freshwater phytoplankton communities are important indicators of the bio-integrity of standing waters and are, therefore, used by the Scottish Environment Protection Agency (SEPA) to assess the ecological status of more than 80 freshwater lochs in Scotland. Phytoplankton samples are collected at varying frequencies, but at a minimum are taken three times a year between July and

September. Sub-samples of phytoplankton (preserved in Lugol's iodine) are examined using an inverted microscope and analysed according to standard procedures, with counts of approximately 400 individuals being routinely conducted (Brierley *et al.*, 2007; CEN, 2004 & 2008). These data not only provide a means of monitoring water quality across Scotland, but also provide information on species distributions, including rare or previously unrecorded species, at the local to national level.

Pseudostaurastrum limneticum (Borge) Chodat occurred sparsely (1 – 2 cells per 10 ml sub-sample) in phytoplankton samples collected from Loch Flemington during the spring and summer months of 2011 and 2012. This comprises the first known record of *P. limneticum* in the U.K. (D. John, *pers. comm.*). Previously, *P. enorme* (Ralfs) Chodat and *P. hastatum* (Reinsch) Chodat were the only two species of *Pseudostaurastrum* recorded from freshwater habitats in Great Britain (Johnson, 2011).

Loch Flemington is located in Nairnshire, around 12 miles east of Inverness, Scotland (NGR: NH 81026 52040). It is a small lake (0.15 km² area), with a shallow mean depth (0.75 m), and is a high alkalinity (annual mean 63.9 mg L⁻¹ as CaCO₃ over 2011-12), meso-eutrophic [annual mean total phosphorus (TP) concentration 39.4 µg L⁻¹ over 2011-12] water body. Due to a long-standing history of potentially toxic cyanobacteria or 'blue-green algae' blooms associated with high phosphorus concentrations, Loch Flemington was subject to a novel lake management approach involving the application (March 2010) of the phosphorus-binding agent, Phoslock®, with the primary goal of improving water quality conditions (Meis *et al.*, 2013). Monitoring of this ecosystem scale experiment continues and includes responses in the phytoplankton community to manipulation of the internal phosphorus load (Lang *et al.*, *unpub. data*). SEPA holds stakeholder interest in the ecological recovery of Loch Flemington, and in collaboration with the Centre for Ecology and Hydrology supports a 'citizen's science' monitoring scheme with local stakeholders to closely monitor water quality through analysis of monthly phytoplankton samples and water chemistry.

Pseudostaurastrum limneticum (Fig. 1a, b) ranges in diameter from 20 – 25 µm, and this bizarre alga can be plate-like, tetrahedral or polyhedral in shape, with cell corners projecting into branches or 'arms' (Schnepf *et al.*, 1996). Morphologically, *P. limneticum* lies in the spectrum between the stout, highly-branched body of *P. enorme* (Fig. 1c), and the slender, tapering form of *P. hastatum* (Fig. 1d). Though *P. limneticum* has been documented worldwide (www.algaebase.org), more specifically this species was found in a small eutrophic lake in

Sicily (Barone, 2003), meso-eutrophic and eutrophic ponds in the Czech Republic (J. Kaštovský, pers. com; www.sinicearasy.cz), and occupying the phosphorus polluted shore waters of Lake Victoria in Tanzania (Mbonde *et al.*, 2004). A preference for nutrient enriched conditions has also been noted elsewhere (e.g., Ott & Oldham-Ott, 2003). These accounts are consistent with the occurrence of *P. limneticum* in the phytoplankton community of Loch Flemington, although this is being further investigated (Lang *et al.*, unpub. data). Ascertaining whether our specimens are a genetic match for *P. limneticum* found in globally distributed freshwater habitats warrants future research.

Pseudostaurastrum limneticum is an unusual species of alga for U.K. freshwaters, and although ecological knowledge is somewhat fragmentary, its occurrence in general suggests elevated nutrient levels. Above all, this represents an exciting new find for the British Isles.

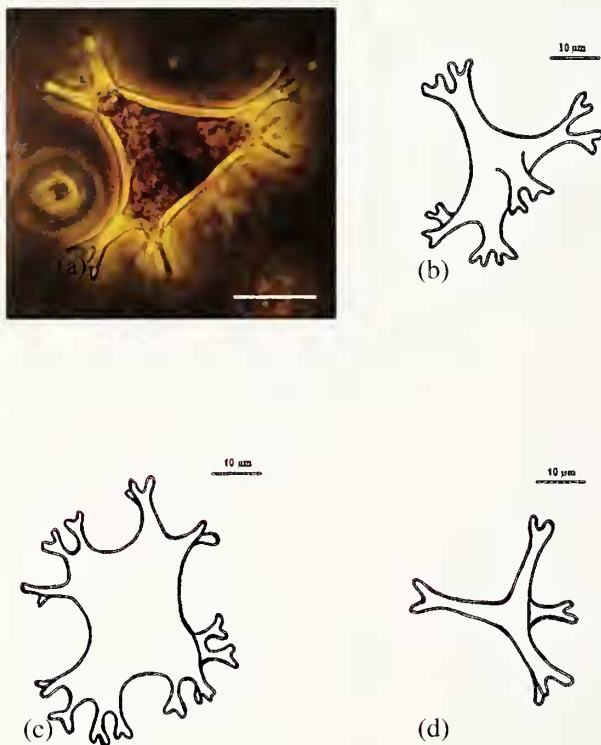


Fig. 1. *Pseudostaurastrum* spp. (a) Photomicrograph of *P. limneticum* preserved in Lugol's iodine. Scalebar, 10 µm. (b) Line drawing of *P. limneticum*. (c) Line drawing of *P. enorme*. (d) Line drawing of *P. hastatum*.

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Thanks especially to Professor David John (Natural History Museum, London) for formally verifying the identity of *P. limneticum*. We are grateful to Dr Elizabeth Haworth (Freshwater Biological Association) for confirming that no U.K. records of *P. limneticum* pre-existed in the Fritsch Collection. We thank SEPA for providing the water chemistry data for Loch Flemington. We also thank Dr Kevin

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The solitary planktonic chrysophyte *Dinobryon faculiferum*: an alga species typically restricted to brackish environments found inhabiting a freshwater loch in northern Scotland

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Dinobryon faculiferum (Willén) Willén [= *Dinobryon petiolatum* T. Willén] is a solitary planktonic chrysophyte ('golden') alga (Lang *et al.*, 2011) typically restricted to brackish environments (Willén, 1963), and hence not currently recognized in John *et al.* (2011). One of several solitary life forms in the genus, *Dinobryon faculiferum* is distinguished from similar species (e.g., *D. borgei*) by a prominently elongate spine, length usually 40 – 60 μm (Willén, 1963), although this characteristic feature can at times be quite variable (Willén, 1992) (Fig. 1a, b). Although primarily documented from sea water (e.g., Unrein *et al.*, 2010), *D. faculiferum* has also been recorded amongst the phytoplankton of a saline lake in Venezuela (Lewis & Riehl, 1982) but never previously from U.K. freshwater habitats.

In the course of analysing phytoplankton samples collected as part of the Scottish Environment Protection Agency's ongoing assessment of the ecological status of freshwater lochs in Scotland (Lang *et al.*, 2013), *Dinobryon faculiferum* was observed sporadically (e.g., 1 – 3 cells per 100 ml sub-sample) in Loch Kinord, between 2009 and 2012, and often co-occurred with a number of other *Dinobryon* species (e.g., *D. bavaricum*; *D. borgei*; *D. crenulatum*; *D. divergens*; *D. sociale*; *D. suecicum*).

Loch Kinord is a freshwater loch in northern Scotland, located approximately 50 km inland from the North Sea coastline. Its water quality characteristics have been described elsewhere (Lang *et al.*, 2012). Perhaps the water environment

provided by Loch Kinord is slightly brackish (annual mean sodium and chloride concentrations respectively 9.23 mg L⁻¹ and 18.05 mg L⁻¹ in 2012), which generally fits in with the current distribution pattern of *D. faculiferum* (Willén, 1963; Unrein *et al.*, 2010). However, this constitutes the first known record of the species from British freshwaters (D. John, *pers. comm.*).

Although widely-regarded as a marine species, we have shown that *D. faculiferum* is also capable of inhabiting freshwater environments. Whether our Scottish specimens of *D. faculiferum* are genetically similar to coastal populations derived from elsewhere in Europe remains to be determined, but identifies an area that would benefit from further research.

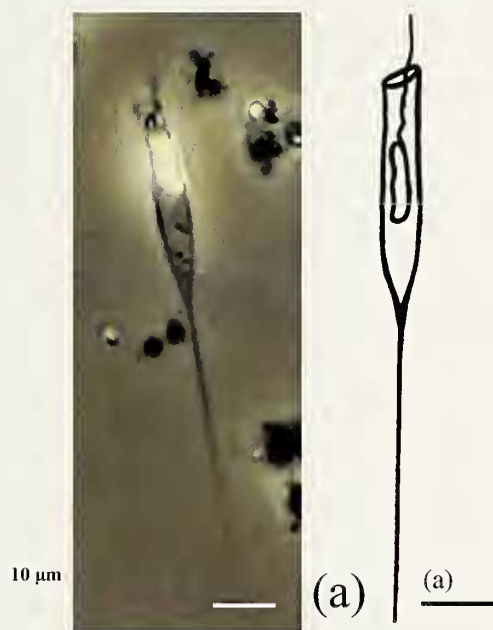


Fig. 1. *Dinobryon faculiferum*. (a) Photomicrograph of *D. faculiferum* preserved in Lugol's iodine. Scalebar, 10 μm . (b) Line drawing of *D. faculiferum*.

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